AD-A099 238 HARRY DIAMOND LABS ADELPHI MD F/6 20/14
USER'S MANUAL FOR ELECTROMAGNETIC PULSE COUPLING CODE TEMPO.(U)
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# REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

| | |
|---|---|
| 1. REPORT NUMBER: 14 HDL-TM-81-2 | 2. GOVT ACCESSION NO.: AD-A099 238 |
| 3. RECIPIENT'S CATALOG NUMBER | |
| 4. TITLE (and Subtitle): User's Manual for Electromagnetic Pulse Coupling Code TEMPO | 5. TYPE OF REPORT & PERIOD COVERED: 9 Technical Memo[redacted] |
| 6. PERFORMING ORG. REPORT NUMBER | |
| 7. AUTHOR(s): 10 Werner J. Stark, David A. Clark, Roy E. Strayer, Jr. | 8. CONTRACT OR GRANT NUMBER(s): 16 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS: Harry Diamond Laboratories, 2800 Powder Mill Road, Adelphi, MD 20783 | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: DA: 1L162120AH25, Program Ele: 6.21.20.A |
| 11. CONTROLLING OFFICE NAME AND ADDRESS: U.S. Army Materiel Development and Readiness Command, Alexandria, VA 22333 | 12. REPORT DATE: 11 Feb[redacted]81 |
| | 13. NUMBER OF PAGES: 37 12 21 |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) | 15. SECURITY CLASS. (of this report): UNCLASSIFIED |
| | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

HDL Project: X759E3
DRCMS Code: 612120.H250011

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

| | |
|---|---|
| EMP | Norton equivalent circuit |
| Interactive computer code | EMP vulnerability assessment |
| Electromagnetic coupling | Thevenin equivalent circuit |
| Antenna response | Electromagnetic pulse |

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A computer code, TEMPO, has been developed to aid in the solution of electromagnetic pulse (EMP) coupling problems. The code is general in nature. It provides approximate solutions to simplified, but practical problems that are commonly encountered during system evaluations. With the aid of TEMPO, an engineer may rapidly determine which sources of coupling are a threat to his system and, consequently, spend more effort on solving those problems than searching for them. This report depicts the organization and the operation of TEMPO on Harry Diamond Laboratories' IBM System/370.

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FIGURES

## 1. INTRODUCTION

Most of the presently available codes for computing the solution to an electromagnetic transient problem are written to solve a specific class of problems. If one is interested in solutions to several different types of problems, one must acquire familiarity with a number of different codes. Each code must be examined for its range of validity, and it may have to be modified to fit specific needs. This process may be prohibitively time-consuming, particularly if one is interested in approximate solutions for a wide variety of problems, rather than a very accurate solution to a specialized case. It is the former type of solution, combined with information about the antenna or cable impedance, that often suffices for a vulnerability analysis of a given circuit attached to the antenna or the cable.

The computer code TEMPO was developed with the objective of providing approximate solutions for a wide class of electromagnetic pulse (EMP) interaction problems in a form usable by a circuit analysis code. The application of TEMPO was to be simple and efficient so that the user would require a minimum amount of familiarity with the code, and the code was to be flexible so that a wide variety of solutions could be performed for a number of different conditions. Finally, the problems addressed by TEMPO were to be practical cases that could ultimately be related to commonly occurring problems in an EMP vulnerability assessment.

## 2. CODE ORGANIZATION

Since TEMPO is used in the EMP vulnerability assessment of complex military systems, it is organized so that its application is an integral part of such an assessment. To do so, the EMP coupling source is represented in terms of either a Thevenin or a Norton equivalent circuit, and a circuit analysis is performed on the equivalent circuit and its load. Since the load circuit usually contains nonlinear elements, the circuit analysis is performed in the time domain by using available network analysis codes for circuits with nonlinear elements.

By separating the EMP vulnerability assessment into two parts consisting of the source equivalent circuit and the load circuit, separate teams of investigators can be assigned to the two types of problems. Initially, the coupling analysis can be performed by using simple linear loads for the equivalent circuit, and the load circuit can be analyzed independently from the coupling source by using simple driving sources. After the coupling source equivalent circuit and the load circuit are adequately modeled, they can be combined for a vulnerability assessment.

Most computer programs using a large scale computer (like the Control Data Corp. (CDC) 6000 series or the IBM System/360 or 370 family of computers) are executed in a batch mode. This mode requires that the user prepare a number of control cards for running the program and data cards for supplying the input parameters to the program. Since the process of preparing such cards can be time-consuming, TEMPO allows for an option to generate the necessary information for running the batch job using two interactive programs. These programs are easily executed at a remote teletypewriter terminal and are designed to aid the user to accurately describe the problem that he wants to solve.

With the interactive portion of initiating the batch job completed, the job can be placed in the batch input queue at the central processing site, and output depends on the normal turnaround

time at the computer center. By running the programs in batch mode, there are no limitations on the size of the programs that can be executed, except for those normally applicable to a batch job. In principle, TEMPO could initiate any pertinent EMP interaction code previously run in a batch mode on a large scale computer.

The result of the computation initiated by TEMPO is normally obtainable in the form of a plot of the transient response. The plot devices can be a remote line printer, a remote x-y bed plotter, or a remote teletypewriter. By using the teletypewriter, it is possible to run TEMPO and obtain an output even if the only remote terminal available to the user is a teletypewriter.

The programs described in this report were written to run on an IBM System/370 Model 168 computer using the time sharing option (TSO)[1] for the interactive portions. They were originally developed to run on a CDC Model 6700 computer using INTERCOM[2] for the interactive portions. Hence, TEMPO can be run on either system with only a few minor changes from one version to the other.

## 3. DESCRIPTION OF TEMPO PROGRAMS

### 3.1 *Interactive Programs*

The present version of TEMPO is written to provide approximate solutions to basic practical coupling problems for interactions with cables, antennas, and apertures. There are many programs and subroutines used for performing the calculations. However, the user need concern himself only with the following two interactive programs for initiating the computation process.

#### 3.1.1 *Program INPUT*

Interactive program INPUT allows the user to select one of five options. Three of the options (ANTENNA, CABLE, and APERTURE) lead to solutions of coupling problems by using theoretical models. The CW (continuous wave) option uses measured frequency-domain data to describe the coupling. The FIELD option does not solve a coupling problem, but allows the user to access program DRIVE without unwanted computations. After specifying a coupling problem, the user is asked to supply information appropriate to that problem. For example, if the choice is ANTENNA, he is asked to describe the antenna, specify the load at the terminal, and add other facts. The user has an option to obtain a brief synopsis of the model used for the computation, including references for additional information on the problem being solved. Once all the parameters for a given problem are defined, the user is asked if he wants output for intermediate steps in the computation. These could be, for example, the frequency spectrum for the transfer function, the impulse response, or the driving field. Finally, he must specify the output medium for any intermediate steps and the transient response for the problem.

#### 3.1.2 *Program DRIVE*

Interactive program DRIVE prompts the user to enter the type of incident field to be used for the problem. Several options for the incident field are available:

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[1] *OS/VS2 TSO Command Language Reference, IBM Technical News Letter GC28 0646 3 (July 1976)*
[2] *6000 Series INTERCOM 3 Reference Manual, Control Data Corp Publication 60252800 Rev B (January 1972)*

a. A data file, such as an experimentally determined incident field

b. One of several types of analytic functions (a Gaussian pulse, a sum of two or four exponential curves, a damped sinusoid, a square wave, or a step wave)

c. A high altitude incident field whose wave shape can have one of the six functional forms in option b

d. An approximation to the surface burst EMP

Once the choice of the incident field has been made, there is an option to compute the driving field either in the time domain or in the frequency domain. If the incident field is determined from experimental data in the time domain, then there is no choice. However, if the incident field is an analytic function, then computational error generally is minimized by specifying the driving field to be computed in the frequency domain.

3.1.3 *Features of Interactive Programs*

An attempt has been made to anticipate questions that a user might have during an interactive session, and information is provided to the user in response to a HELP command. For example, the user may be asked to specify the type of coupling problem. If he issues a HELP command, the program gives him information on what types of coupling problems can be solved by using TEMPO.

After the interactive session is completed, a batch job is generated. This job can be submitted through TSO to the batch input queue by issuing a SUBMIT'HK3010.JOB.CNTL' command. Alternatively, if a punched deck of the job was requested during the interactive session, this punched deck can be submitted independently of TSO. Once a punched deck for the job has been obtained, this job can be submitted through a card reader at a batch terminal.

3.2 *Batch Programs*

The remaining programs perform the numerical computations and generate an output for the problem specified. They consist of several independent mainline programs and subroutines that pass pertinent data to one another via temporary data sets. Which program is executed depends on the type of problem being solved. For example, the INVERT (inverse Fourier transform) program may or may not be required, depending on whether or not the computations are performed in the time domain. The following sections and appendix A describe the mainline programs and their subroutines.

3.2.1 *Procedure IO*

Although not a FORTRAN program, procedure IO initiates all of the files to be used for inputting, outputting, and transferring data. This procedure creates a file on unit 2 called the IO file and then stores the input-output control (IO) data on the file. The IO file is then read by each program. It both passes pertinent coupling parameters from one program to the next and controls the task of each program. The IO file also stores any measured data submitted with the job.

### 3.2.2 *Program FRQ*

Mainline program FRQ reads the IO file, defines the problem to be solved, and calls the appropriate subroutine to compute the frequency spectrum for the response. After the frequency spectrum is computed, the resulting effective height and antenna impedance are written on two separate files for further analysis. Subsequent Fourier transforms are computed for 2048 equispaced frequency points by using the fast Fourier transform (FFT) or for 256 equispaced frequency points by using the LFILON transform.

### 3.2.3 *Program ZANT*

Program ZANT computes a lumped parameter network (LPN) equivalent to the antenna impedance for the problem being solved. The program is used if a time-domain equivalent circuit is required to represent the coupling problem. It applies when the antenna impedance shows multiple isolate resonances, so that the antenna impedance is easily represented as a series of parallel resonant circuits.

### 3.2.4 *Program FIELD*

Program FIELD computes the incident electric field either in the frequency domain or in the time domain as specified by the user. The subsequent convolution with the impulse response for the problem is performed in the corresponding frequency or time domain. The options available for computing various types of fields have been described in the discussion of interactive program DRIVE.

### 3.2.5 *Program CONVOL*

Program CONVOL computes the convolution of two functions, (1) the incident field and (2) the impulse response for current or voltage for a given coupling problem. For a field scattered by an aperture, the second function is the impulse response of the aperture. If both functions are in the frequency domain, the product remains in the frequency domain. If both functions are in the time domain, the convolution integral is performed by using a simple numerical integration in the time domain.

### 3.2.6 *Program FOURIER*

Program FOURIER transforms any one of three types of frequency spectra from the frequency domain to the time domain: (1) the effective height of the current or voltage for a given coupling problem or the transfer function for the field scattered by an aperture, (2) the electric field component for the incident or ground-interacted field, or (3) the product of two functions such as the incident field and the effective height of an antenna.

The Fourier transform is performed by using either (1) the Cooley-Tukey[3] algorithm for the FFT or (2) a numerical integration combining trapezoidal and Filon techniques (LFILON).[4] The FFT is used in most cases, and the LFILON transform is available to verify the results obtained by

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[3] *J. W. Cooley and J. W. Tukey, An Algorithm for the Machine Calculation of Complex Fourier Series, Mathematics of Computation,* **19** *(April 1965)*

[4] *D. G. Dudley, Numerical Inversion of the Fourier Transform, A Combination Trapezoidal and Filon Technique, Lawrence Livermore Laboratories, Livermore, CA, UCRL-51878 (1975)*

using the FFT. The FFT is performed by using 2048 equispaced frequency points, whereas the LFILON transform is performed by using 256 points. At present, the frequency points are equispaced for the LFILON transform. However, in general, the LFILON transform can be used with an arbitrary number of points with arbitrary spacings in the time domain, the frequency domain, or both.

### 3.2.7 *Program OUTPUT*

Program OUTPUT controls the output processing for a given run. The various selected computed functions are plotted on a bed plotter, a line printer, or a teletypewriter, depending on which device was specified as an output device. The plot routines are described elsewhere for the bed plotter[5] and for plots on the printer.[6]

## 4. METHODS FOR EXCHANGING DATA BETWEEN BATCH PROGRAMS

Since TEMPO is a composite of various single purpose programs, the data must be passed from one program to the next. Likewise, the instruction set and the problem parameters must be accessed by each program. The following sections describe the input-output controls, the parameters, and the file allocations.

### 4.1 *Definition of Temporary Data Sets*

| Tape unit | File name | Type of data |
|---|---|---|
| 1 | — | Temporary data storage used by program OUTPUT |
| 2 | IO | Input-output and problem definition parameters |
| 3 | FIMP | Frequency-domain impulse response spectrum |
| 4 | IMPLS | Time-domain impulse response spectrum |
| 5 | FIELD | Time-domain electric field |
| 6 | PRINT | Output to printer or teletypewriter |
| 7 | SYSOUT=B | Output to bed plotter |
| 8 | FFIELD | Frequency-domain electric field |
| 9 | FRESP | Frequency-domain response to incident field |
| 10 | RESP | Time-domain response to incident field |
| 11 | ZA | Antenna and cable impedance |

[5] T. V. Noon, *Enhanced Plotting Software for Use with the Houston Instrument COMPLOT Plotter*, Harry Diamond Laboratories HDL-TM-75-32 (December 1975).
[6] Egon Marx, *Printer Version of Plots Made by an Incremental Plotter*, Harry Diamond Laboratories HDL-TM-75-33 (December 1975).

4.2 *Description of IO Data Cards*

| Card | Label | Description |
|---|---|---|
| 1 | t | Time increment for computing transient wave shape |
| 2 | IOFLAG (I), I = 1 to 10 | Flags to indicate which type of output and which type of output medium are desired |
| 3 | FLAG (I), I = 1 to 20 | Flags to describe type of problem to be solved and type of field to be computed; also referred to as FLAG IA, IB, . . ., IR |
| 4 to 7 | PARAM (I), I = 1 to 20 | Parameters to describe geometry and physics of scattering object |
| 8 to 10 | FPAR (I), I = 1 to 18 | Parameters to describe incident electric field for problem |

4 3 *Definitions for Input-Output Flags*

| Term | | Definition |
|---|---|---|
| MULCURVE | IOFLG9 | =1, 2, . . ., Depending on whether RESP, FIELD, . . ., contain multiple curves |
| NCURVE | IOFLG10 | =Number of curves − 1 that are to be plotted if MULCURVE ≠ 0 |
| FSPEC | IOFLG4 | =0 plot magnitude and phase<br>=1 plot real and imaginary |

IOFLG(I), I = 1, 2, 3, 5, 6, 7, 8, are the outputs of files RESP, FIELD, IMPLS, FRESP, FFIELD, FIMP, and ZA, respectively, and are plotted in accordance with IOFLG4 and the following:

Linear x and y scales:
IOFLG(I) =1 plot output on teletypewriter
=2 plot output on printer
=3 plot output on plotter
Allowed values for IOFLG(I) I = 1, 2, 3, 5, 6, 7, 8

Linear x scale, log y scale for magnitude, real, imaginary
and
Linear x scale, linear y scale for phase:
IOFLG(I) =5 plot output on printer
=6 plot output on plotter
Allowed values for IOFLG(I) I = 5, 6, 7, 8

Log x scale, log y scale for magnitude, real, imaginary
and
Log x scale, linear y scale for phase:
IOFLG(I) =8 plot on printer
=9 plot on plotter
Allowed values for IOFLG(I) I = 5, 6, 7, 8

4.4 *Flag Card*

The flag card has 20 integers in columns 1 to 20: flags IA to IT. The flags control the routing within the mainline programs and the subroutines so that the desired problem will be solved. Figures 1 to 8 indicate the uses of the flags.

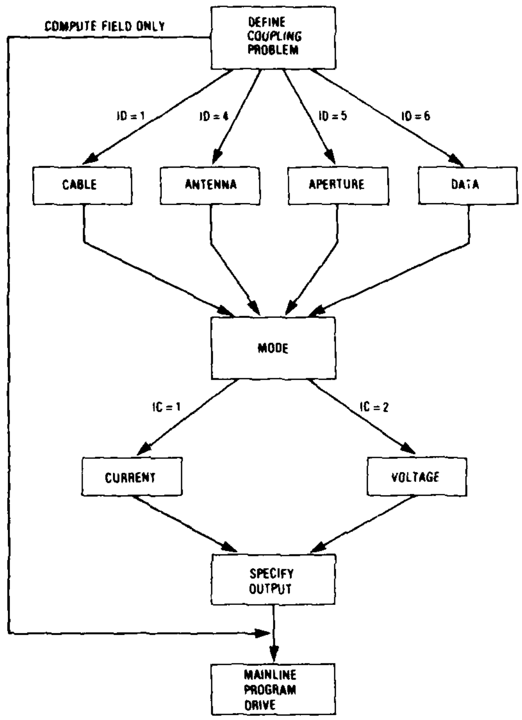


Figure 1. Definition of flags IC, ID (mainline—INPUT).

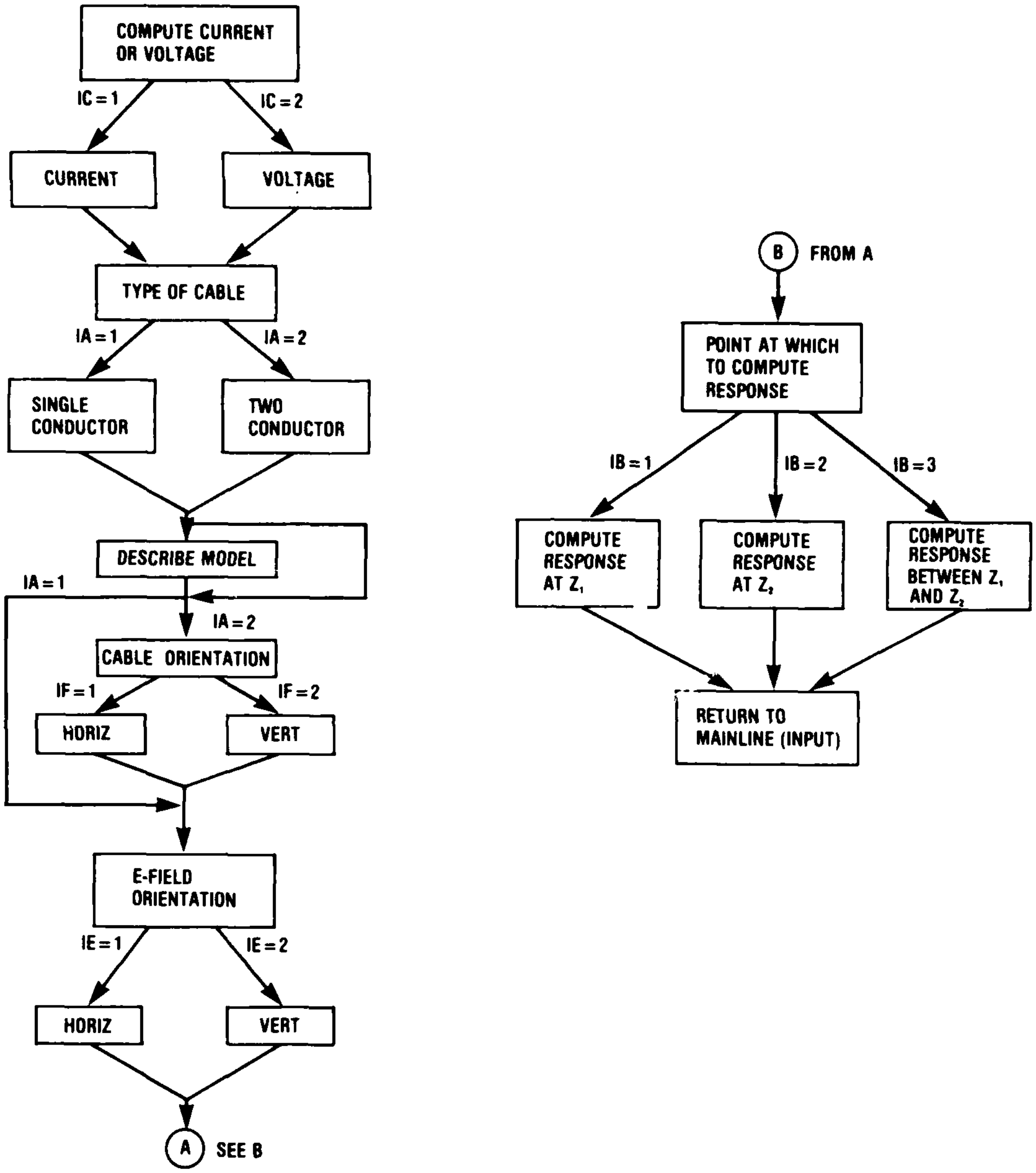


Figure 2. Definition of flags IA, IB, IC, IE, IF (CABLE).

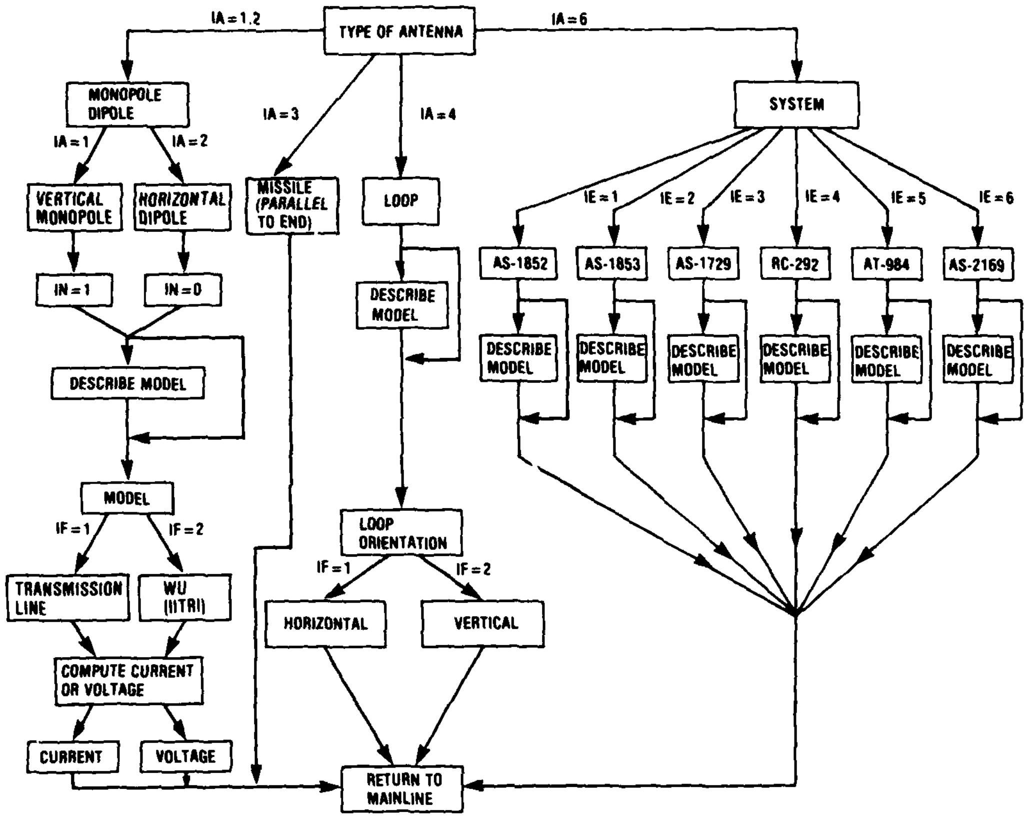


Figure 3. Definition of flags IA, IE, IF, IN (ANTENNA).

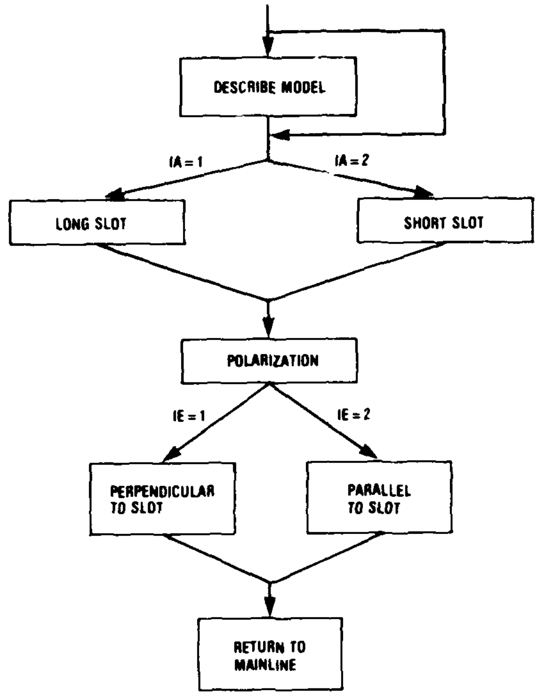


Figure 4. Definition of flags IA, IE (APERTURE).

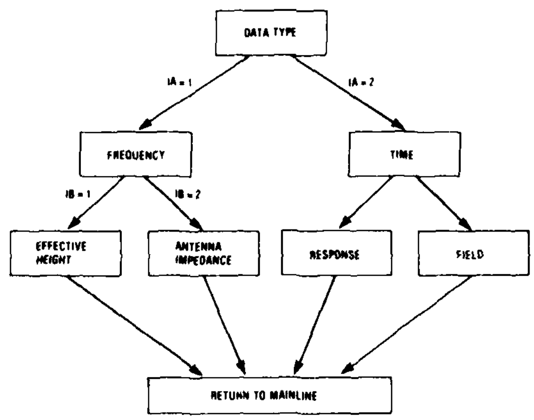


Figure 5. Definition of flags IA, IB (DATA).

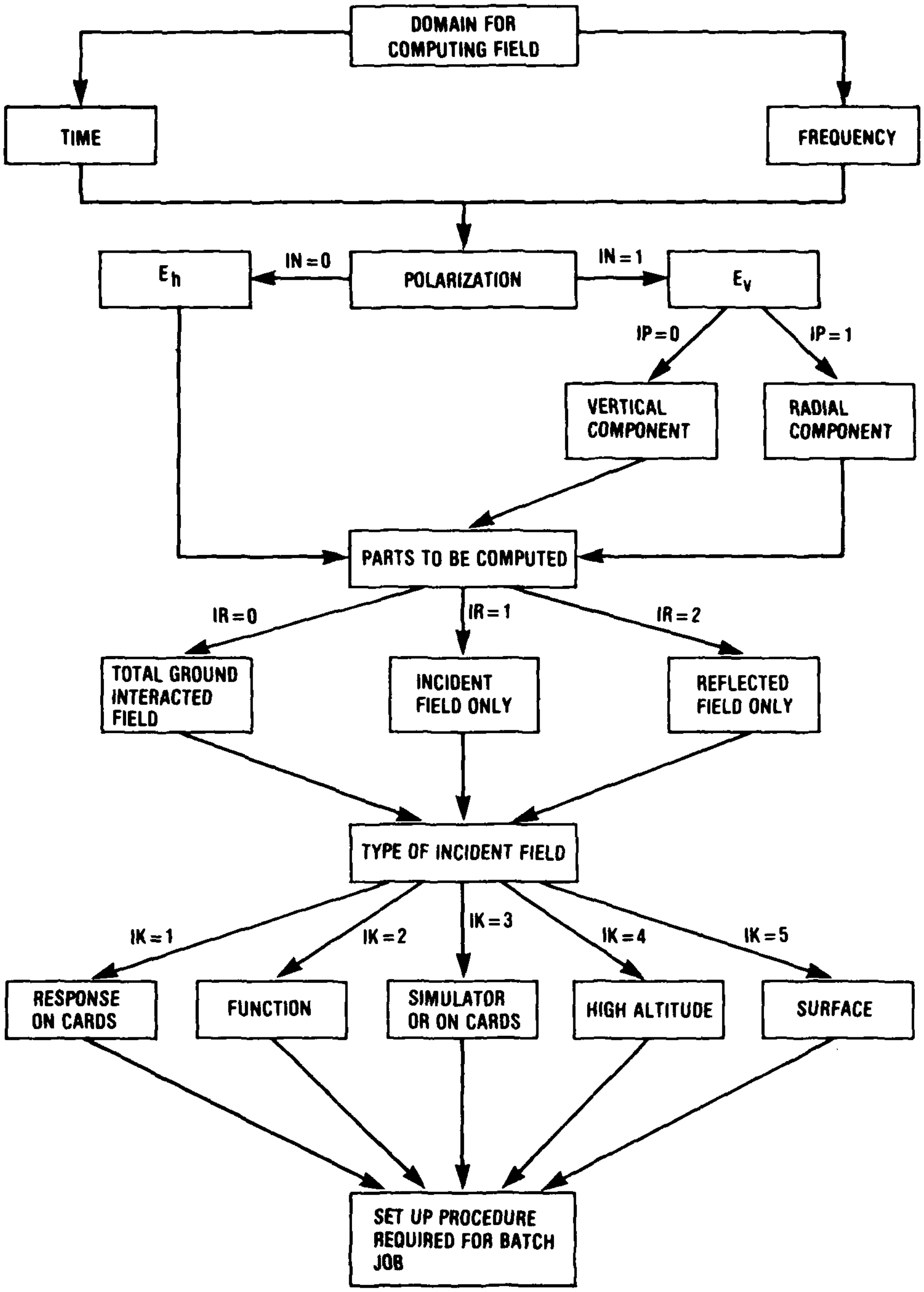


Figure 6. Definition of flags IK, IM, IN (mainline—DRIVE).

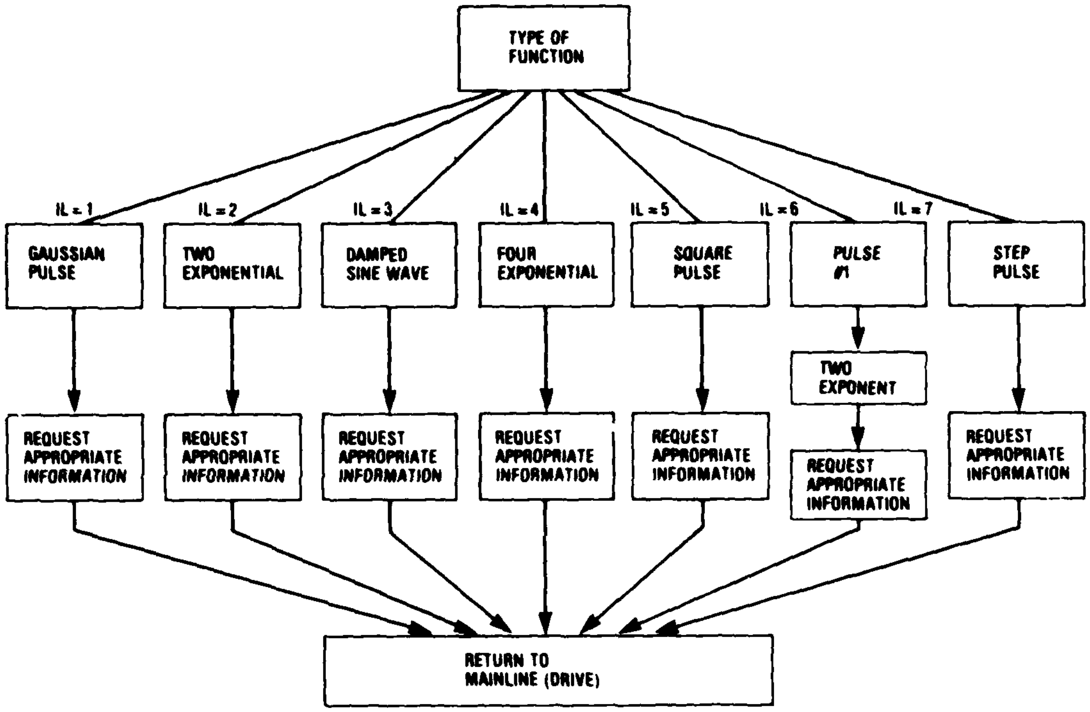


Figure 7 Definition of flag IL (FUNCTION)

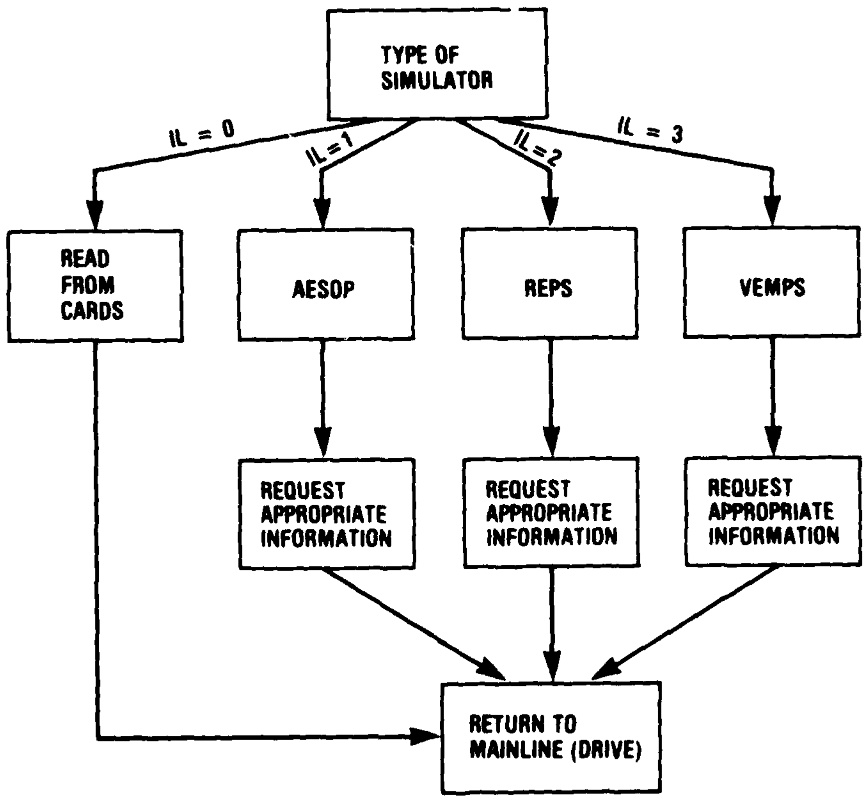


Figure 8. Definition of flag IL (SIMULATOR)

The following flags are used in additon to those defined in figures 1 to 8.

| Flag | Description |
|---|---|
| IH | Computation of equivalent network for antenna impedance<br>IH = 0 computation not required<br>IH = 1 computation required |
| IS | Method used for computing Fourier transform<br>IS = 0 use FFT<br>IS = 1 use LFILON transform |
| IT | Debug option<br>IT = 0 no debug option<br>IT = 1 debug option desired |

4.5 *Definition of ARRAY Parameters (PARAM) 1 to 20*

| Parameter | Definition |
|---|---|
| PARAM(1) | = RHO (resistivity) definition when solving cable problem<br>RHO = − 5E−5 if analytical model C1 is used<br>RHO = 1 /SIGMA (SIGMA = ground conductivity) if analytical model C2 is used |
| PARAM(2) | For cable problem, = R1 of series resistance-inductance-capacitance (RLC) at cable terminals (ohms).<br>For antenna problem, = R of RLC load at antenna feed point (ohms)<br>For continuous wave (cw) problem, = R = load resistance (ohms)<br>For aperture problem, = H = length of aperture (meters). |
| PARAM(3) | For cable problem, = L1 of series RLC at cable terminals (henries)<br>For antenna problem, = L of RLC load at antenna feed point (henries)<br>For cw problem, = IND= load inductance (henries).<br>For aperture problem, = W = width of aperture (meters) |
| PARAM(4) | For cable problem, = C1 of series RLC at cable terminals (farads)<br>For antenna problem, = C of RLC load at antenna feed point (farads)<br>For cw problem, = C = load capacitance (farads)<br>For aperture problem, = R = distance from aperture for computing electric field (meters) |
| PARAM(5) | For cable problem, = R2 of series RLC at cable terminals (ohms)<br>For antenna problem,<br>= H = length of antenna for monopole and dipole antennas (meters)<br>= B = loop radius for loop antennas (meters)<br>= H = missile length for missile problems (meters)<br>= H1 = 0.3 for AS1852 antenna, = 0.35 for AS1852 antenna (meters) |

| Parameter | Definition |
|---|---|
| PARAM(6) | For cable problem, = L2 of series RLC at cable terminals (henries).<br>For antenna problem,<br>= D = antenna diameter for dipoles or monopoles (millimeters).<br>= R = wire radius for loop antennas (meters).<br>= A = missile radius for missile problem (meters).<br>For cw problem, = RES = antenna resistance (ohms). |
| PARAM(7) | For cable problem, = C2 of series RLC at cable terminals (farads).<br>For antenna problem,<br>= X = H*XIN (H = missile length) representing relative position between missile tail and missile nose for current calculations (XIN = decimal number between 0. and 1.).<br>= X = HP*XIN (HP = missile plume length) representing relative position between plume tip and missile tail for current calculations (XIN = decimal number between −1. and 0.).<br>= LL = 2000 for system antennas AS1852 and AS1853. |
| PARAM(8) | For cable problem, = L = cable length (meters).<br>For antenna problem,<br>= HP = plume length for missile problem (meters).<br>= ZO1 = 50 for system antennas. |
| PARAM(9) | For cable problem, = X = value between 0. and 1. representing fractional distance along cable for computing response.<br>For antenna problem,<br>= R1 of series RLC termination on cable connected to antenna for system antennas (ohms).<br>= SIGMA = plume conductivity for missile problems.<br>= 1.E7 (automatically) if plume length = 0. |
| PARAM(10) | For cable problem, = H = height of cable aboveground (meters).<br>For antenna problem,<br>= HG = height of antenna terminal aboveground for system, loop, monopole, and dipole antennas (meters).<br>= HG = height of missile aboveground for missile problem (meters).<br>For cw problem, = HG = height of test point aboveground (if antenna resistance is greater than zero) (meters).<br>For aperture problem, = HG = height of center of aperture aboveground (meters). |
| PARAM(11) | For cable problem, = D = conductor diameter (meters).<br>For antenna problem,<br>= L1 of series RLC termination on cable connected to antenna for system antennas (henries).<br>= ALPHA = damping constant for missile problems. |
| PARAM(12) | For cable problem, = S = separation distance between cables for two-conductor cable (meters).<br>For antenna problem,<br>= RP1 = inner plume radius for missile problem (meters).<br>= C1 of series RLC termination on cable connected to antenna for system antennas (farads). |

| Parameter | Definition |
|---|---|
| PARAM(13) | For antenna problem, = outer plume radius for missile problem (meters). For frequency plot, = multiple of frequency increment (DF). |
| PARAM(14) | For frequency plot, = maximum frequency for response plot (hertz). |
| PARAM(15) | For frequency plot, = maximum frequency for field plot (hertz). |
| PARAM(16) | For frequency plot, = maximum frequency for impulse plot (hertz). |
| PARAM(17) | For frequency plot, = maximum frequency for impedance plot (hertz). |
| PARAM(18) | For time-domain output, = maximum time for transient output (hertz). |
| PARAM(19) | For time-domain output, = maximum time for field plot (hertz). |
| PARAM(20) | For time-domain output, = maximum time for impulse plot (hertz). |

### 4.6 *Definitions of Field Parameters (FPAR) 1 to 18*

| Parameter | Definition |
|---|---|
| FPAR (1) | For function-described field, = peak amplitude (volts/meter) = YMAX.<br>For simulator field, = YMAX = peak free field at 50 m.<br>For surface field, = YMAX. |
| FPAR (2) | For Gaussian field, = WIDTH = pulse width (nanoseconds).<br>For two-exponential field, = ALPHA = one of two decay constants (per second).<br>For sine-function field, = OMEGA = (2*PI)/PERIOD *1.E9 (PERIOD in nanoseconds).<br>For four-exponential field, = ALPHA = one of four decay constants.<br>For square-wave field, = WIDTH = pulse width (nanoseconds).<br>For surface field, = ALPHA. |
| FPAR (3) | For two-exponential field, = BETA = one of two decay constants (per second).<br>For sine-function field, = ALPHA = 1.E9/e-folding time (e-folding time in nanoseconds).<br>For four-exponential field, = BETA = one of four decay constants.<br>For surface field, = BETA. |
| FPAR (4) | For four-exponential and surface field, = GAMMA = one of four decay constants. |
| FPAR (5) | For four-exponential and surface field, = ETA = one of four decay constants. |
| FPAR (6) | For four-exponential and surface field, = A1 = one of the three "weighting" constants. |
| FPAR (7) | For four-exponential and surface field, = A2 = one of three "weighting" constants. |

| Parameter | Definition |
|---|---|
| FPAR (8) | For four-exponential and surface field, = A3 = one of three "weighting" constants. |
| FPAR (9) | For simulator field, = R0 = radial distance from simulator (meters).<br>For high altitude field, = THETA = angle of incident field with respect to ground (degrees). |
| FPAR (10) | For simulator field, = R2 = height of simulator aboveground.<br>For all other fields, = PHI = polarization angle of total E-field vector measured up from horizontal (degrees). |
| FPAR (11) | For computing reflected component of high altitude incident field, = SIGMA = ground conductivity (default value = 0.01 mho). |
| FPAR (12) | For computing reflected component of high altitude incident field, = EPSILON = ground dielectric constant (default value = 15). |
| FPAR (13) | For following three cases (loop antennas only), FPAR (13 to 18) have following values: |

For loop horizontally oriented with THETA (angle of field with respect to ground) less than or equal to 45 deg (orientation of E-field's polarization is unimportant here).

For loop vertically oriented with E-field vertically polarized parallel to plane of loop (THETA must be less than or equal to 45 deg).

For loop vertically oriented with E-field horizontally polarized (no restrictions on field's orientation with respect to loop (THETA must be greater than 45 deg).

| | |
|---|---|
| FPAR (13) = EX = 0. | FPAR (16) = L = −1. |
| FPAR (14) = EY = 1. | FPAR (17) = M = 0. |
| FPAR (15) = EZ = 0. | FPAR (18) = N = 0. |

For following three cases (for loop antennas only), FPAR (13 to 18) have following values:

For loop horizontally oriented with THETA greater than 45 deg (orientation of E-field's polarization is unimportant).

For loop vertically oriented with E-field vertically polarized perpendicular to plane of loop (THETA must be greater than 45 deg).

For loop vertically oriented with E-field horizontally polarized (no restrictions on field's orientation with respect to loop) (THETA must be less than or equal to 45 deg).

| | |
|---|---|
| FPAR (13) = EX = 0. | FPAR (16) = L = 0. |
| FPAR (14) = EY = 1. | FPAR (17) = M = 0. |
| FPAR (15) = EZ = 0. | FPAR (18) = N = −1. |

## LITERATURE CITED


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APPENDIX A.—PROCEDURES FOR COMPUTER CODE TEMPO

APPENDIX A

CONTENTS

## A-1. PROCEDURE TEMPO

Procedure TEMPO (listing A-1) can be used through the time sharing option (TSO) to execute interactive programs INPUT and DRIVE. After procedure TEMPO is completed, the new batch job can be submitted to the job stream by specifying a SUBMIT JOB command. The various data sets such as IO, CW, and JOB can be examined and altered by using the TSO EDIT command.

Listing A-1. Procedure TEMPO

```
PROC 0
CONTROL NOMSG
FREE FILE(FT01F001,FT02F001,FT03F001,FT04F001,FT05F001,FT07F001)
CONTROL MSG
ALLOCATE DSNAME(*) FILE(FT01F001)
ALLOCATE DSNAME(*) FILE(FT02F001)
ALLOCATE DSNAME(IO) FILE(FT03F001)
ALLOCATE DSNAME(JOB.CNTL) FILE(FT04F001)
ALLOCATE DSNAME(CWDAT) FILE(FT05F001)
ALLOCATE SYSOUT(B) FILE(FT07F001)
FORTGO (INPT)
FORTGO (DRIVE)
CONTROL NOMSG
FREE FILE(FT01F001,FT02F001,FT03F001,FT04F001,FT05F001,FT07F001)
CONTROL MSG
END OF DATA
```

## A-2. PROCEDURE IO

Procedure IO (listing A-2) is used the first time that the IO parameters are to be read from cards. At the same time, all temporary data sets to be used in a TEMPO batch job are defined.

Listing A-2. Procedure IO

```
//IOH      PROC
//* TOM HARRIS,303-599-1745, 1 JULY 1980    , INDEFINITE
//* INITIATES INPUT AND DATA FILES
//*
//*THIS PROCEDURE READS IN 10 DATA CARDS USED TO DESCRIBE THE PROBLEM
//*     TO BE EXECUTED BY TEMPO.  THIS INCLUDES DT,IOFLAG(I), FLAG(I),
//*     PARAM(I), AND FPAR(I)
//*
//COPY  EXEC  PGM=IEBGENER
//SYSIN DD DUMMY
//SYSPRINT DD DUMMY
//SYSUT2 DD DSN=&&IO,DISP=(NEW,PASS),UNIT=SYSDA,
//         SPACE=(TRK,(1,1)),
//         DCB=(RECFM=FB,LRECL=80,BLKSIZE=800)
//FT03F001  DD  DSN=&&FIMP,DISP=(NEW,PASS),
//          UNIT=VIO,SPACE=(TRK,(1,1)),
//          DCB=(RECFM=VS,BLKSIZE=4096)
//FT04F001  DD  DSN=&&IMPLS,DISP=(NEW,PASS),
//          UNIT=VIO,SPACE=(TRK,(1,1)),
//          DCB=(RECFM=VS,BLKSIZE=4096)
//FT05F001  DD  DSN=&&FIELD,DISP=(NEW,PASS),
//          UNIT=VIO,SPACE=(TRK,(1,1)),
//          DCB=(RECFM=VS,BLKSIZE=4096)
//FT06F001  DD  DSN=&&PRINT,DISP=(NEW,PASS),
//          UNIT=VIO,SPACE=(TRK,(9,9)),
//          DCB=(RECFM=FA,LRECL=133,BLKSIZE=133)
//FT07F001  DD  DSN=&&PUNDATA,DISP=(NEW,PASS),
//           UNIT=VIO,SPACE=(TRK,(1,1)),
//         DCB=(RECFM=FB,LRECL=80,BLKSIZE=800)
//FT08F001  DD  DSN=&&FFIELD,DISP=(NEW,PASS),
//          UNIT=VIO,SPACE=(TRK,(1,1)),
//          DCB=(RECFM=VS,BLKSIZE=4096)
//FT09F001  DD  DSN=&&FPROD,DISP=(NEW,PASS),
//          UNIT=VIO,SPACE=(TRK,(1,1)),
//          DCB=(RECFM=VS,BLKSIZE=4096)
//FT10F001  DD  DSN=&&RESP,DISP=(NEW,PASS),
//          UNIT=VIO,SPACE=(TRK,(1,1)),
//          DCB=(RECFM=VS,BLKSIZE=4096)
//FT11F001  DD  DSN=&&ZA,DISP=(NEW,PASS),
//          UNIT=VIO,SPACE=(TRK,(1,1)),
//          DCB=(RECFM=VS,BLKSIZE=4096)
//FT20F001  DD  DSN=&&NLIN,DISP=(NEW,PASS),
//          UNIT=VIO,SPACE=(TRK,(9,9)),
//          DCB=(RECFM=VS,BLKSIZE=4096)
```

## A-3. PROCEDURE IO1

Procedure IO1 (listing A-3) reads cards into a specified temporary data set. The default value for the temporary data set is IO, since this procedure is normally used to read a new set of parameters into the temporary data set IO.

Listing A-3. Procedure IO1

```
//IO1   PROC FILE='&&IO',OUT=X
//*        W. J. STARK, 664-6234, 17 AUG 77, INDEFINITE
//* READS IO DATA
//IO1    EXEC  PGM=IEBGENER
//SYSIN DD DUMMY
//SYSPRINT DD DUMMY
//SYSUT2 DD DSN=&FILE,DISP=(OLD,PASS)
//COPY   EXEC   PGM=IEBGENER,COND=EVEN
//SYSIN DD DUMMY
//SYSPRINT DD DUMMY
//SYSUT1 DD DSN=&FILE,DISP=(OLD,PASS)
//SYSUT2 DD SYSOUT=&OUT
```

## A-4. PROCEDURE IO2

Procedure IO2 (listing A-4) copies a short term or permanent data set into a specified temporary data set. The name of the input data set must be specified on the EXEC statement. The default value for the temporary data set is FIMP, since this procedure is normally used to copy continuous wave (cw) data into the temporary data set FIMP.

Listing A-4. Procedure IO2

```
//IO2  PROC IN=,OUT='&&FIMP'
//*        W. J. STARK, 664-6234, 2[illegible] APR 77, INDEFINITE
//* COPIES FILES
//COPY  EXEC  PGM=IEBGENER
//SYSIN DD DUMMY
//SYSPRINT DD DUMMY
//SYSUT1 DD DSN=&IN,DISP=(OLD,KEEP)
//SYSUT2 DD DSN=&OUT,DISP=(OLD,PASS)
//       EXEC  PGM=IEBGENER,COND=EVEN
//SYSIN DD DUMMY
//SYSPRINT DD DUMMY
//SYSUT1 DD DSN=&OUT,DISP=(OLD,PASS)
//SYSUT2 DD SYSOUT=A
```

## A-5. PROCEDURE FRQ

Procedure FRQ (listing A-5) loads and executes program FRQ with the appropriate subroutine. The appropriate FAMP subroutine must be specified on the EXEC statement. Otherwise, the default value of FAMP 1234 is used. If more than one frequency spectrum is to be computed, then FDISP = MOD must be specified on the EXEC statement.

Listing A-5. Procedure FRQ

```
//FREQH PROC FAMP=FAMP1234,FDISP=OLD,ZDISP=OLD
//* TOM HARRIS,303-599-1745, 1 JULY 1980     , INDEFINITE
//* COMPUTES FAMP FILES
//LKED EXEC    PGM=IEWL,REGION=250K,PARM='NOMAP,LIST,NOXREF,LET'
//*
//*     THIS PROCEDURE EXECUTES THE FREQUENCY IMPULSE RESPONSE MAINLINE
//*     PROGRAM.  THE PROCEDURE CARD MUST HAVE FAMP=FAMPSUBROUTINE TO BE
//*     EXECUTED.
//*
//SYSPRINT  DD DUMMY
//SYSLIB     DD DSN='HK3014.TEMP04',DISP=SHR
//           DD DSN=SYS1.FORTLIB,DISP=SHR
//           DD DSN=SYS1.PAGLOAD,DISP=SHR
//SYSUT1     DD UNIT=SYSDA,SPACE=(1024,(200,20))
//SYSLMOD    DD DSN=&&GOSET(MAIN),UNIT=SYSDA,DISP=(,PASS),
//              SPACE=(TRK,(10,10,2))
//SYSLIN     DD DSN=HK3014.LKEDIN4(&FAMP),DISP=SHR
//FREQ    EXEC PGM=*.LKED.SYSLMOD,COND=(8,LT,LKED)
//FT02F001   DD   DSN=&&IO,DISP=(OLD,PASS)
//FT03F001   DD   DSN=&&FIMP,DISP=(&FDISP,PASS)
//FT06F001   DD   DSN=&&PRINT,DISP=(MOD,PASS)
//FT08F001   DD   DSN=&&FFIELD,DISP=(OLD,PASS)
//FT09F001   DD   DSN=&&FPROD,DISP=(OLD,PASS)
//FT11F001   DD   DSN=&&ZA,DISP=(&ZDISP,PASS)
//FT20F001   DD   DSN=&&NLIN,DISP=(OLD,PASS)
//DD1  DD   DSN=&&GOSET,DISP=(OLD,DELETE)
```

## A-6. PROCEDURE EFIELD

Procedure EFIELD (listing A-6) loads and executes programs EFIELD and EFIEL1. If more than one field is to be computed, FRQ = MOD or TIM = MOD must be specified on the EXEC statement, depending on whether the field computation is in the frequency domain or the time domain.

Listing A-6. Procedure EFIELD

```
//EFIELDH PROC FRQ=OLD,TIM=OLD
//* TOM HARRIS,303-599-1745, 1 JULY 1980    , INDEFINITE
//* COMPUTES EFIELD
//*
//*     THIS PROCEDURE EXECUTES THE EFIELD MAINLINE PROGRAM.
//*
//LKED EXEC    PGM=IEWL,REGION=250K,PARM='NOMAP,LIST,NOXREF,LET'
//SYSPRINT DD DUMMY
//SYSLIB    DD DSN='HK3014.TEMPC4',DISP=SHR
//          DD DSN=SYS1.FORTLIB,DISP=SHR
//          DD DSN=SYS1.PAGLOAD,DISP=SHR
//SYSUT1    DD UNIT=SYSDA,SPACE=(1024,(200,20))
//SYSLMOD   DD DSN=&&GOSET(MAIN),UNIT=SYSDA,DISP=(,PASS),
//             SPACE=(TRK,(10,10,2))
//SYSLIN    DD DSN=HK3014.LKEDIN4(EFIELD),DISP=SHR
//EFLD    EXEC PGM=*.LKED.SYSLMOD,COND=(8,LT,LKED)
//FT02F001   DD   DSN=&&EIO,DISP=(OLD,PASS)
//FT03F001   DD   DSN=&&FIMP,DISP=(OLD,PASS)
//FT05F001   DD   DSN=&&FIELD,DISP=(&TIM,PASS)
//FT06F001   DD   DSN=&&PRINT,DISP=(MOD,PASS)
//FT08F001   DD   DSN=&&FFIELD,DISP=(&FRQ,PASS)
//DD1  DD   DSN=&&GOSET,DISP=(OLD,DELETE)
```

## A-7. PROCEDURE INVERT

Procedure INVERT (listing A-7) loads and executes program INVERT and the appropriate subroutine. The default value for this subroutine is FFT1. Otherwise, FOURIER = LFILON must be specified on the EXEC statement. If the impulse response, the field, or the transient response is to be computed more than once, then IDISP, FDISP, or RDISP, respectively, must be set equal to MOD on the EXEC statement.

Listing A-7. Procedure INVERT

```
//INVERTH PROC   IDISP=OLD,FDISP=OLD,RDISP=OLD,FORIER=FFT1
//* TOM HARRIS,303-599-1745, 1 JULY 1980     , INDEFINITE
//* COMPUTES FFT
//*
//*     THIS PROCEDURE EXECUTES THE FOURIER TRANSFORM  MAINLINE PROGRAM.
//*     AS OF 1 JULY,1980, THIS COMPUTES AN INVERSE FOURIER TRANSFORM,
//*     FREQUENCY TO TIME DOMAIN, AND IT IS EXPECTED TO  COMPUTE A FORWARD
//*     FOURIER TRANSFORM  TIME TO FREQUENCY DOMAIN, IN THE NEAR FUTURE.
//*
//LKED EXEC    PGM=IEWL,REGION=250K,PARM='NOMAP,LIST,NOXREF,LET'
//SYSPRINT DD DUMMY
//SYSLIB     DD DSN='HK3014.TEMP04',DISP=SHR
//           DD DSN=SYS1.FORTLIB,DISP=SHR
//SYSUT1     DD UNIT=SYSDA,SPACE=(1024,(200,20))
//SYSLMOD    DD DSN=&&GOSET(MAIN),UNIT=SYSDA,DISP=(,PASS),
//              SPACE=(TRK,(10,10,2))
//SYSLIN     DD DSN=HK3014.LKEDIN4(&FORIER),DISP=SHR
//FOUR     EXEC PGM=*.LKED.SYSLMOD,COND=(8,LT,LKED)
//FT02F001   DD   DSN=&&IO,DISP=(OLD,PASS)
//FT03F001   DD   DSN=&&FIMP,DISP=(OLD,PASS)
//FT04F001   DD   DSN=&&IMPLS,DISP=(&IDISP,PASS)
//FT05F001   DD   DSN=&&FIELD,DISP=(&FDISP,PASS)
//FT06F001   DD   DSN=&&PRINT,DISP=(MOD,PASS)
//FT08F001   DD   DSN=&&FFIELD,DISP=(OLD,PASS)
//FT09F001   DD   DSN=&&FPROD,DISP=(OLD,PASS)
//FT10F001   DD   DSN=&&RESP,DISP=(&RDISP,PASS)
//DD1   DD   DSN=&&GOSET,DISP=(OLD,DELETE)
```

## A-8. PROCEDURE CONVOL

Procedure CONVOL (listing A-8) loads and executes program CONVOL. If more than one convolution is to be performed, then FRQ = MOD or TIM = MOD must be specified on the EXEC statement, depending on whether the convolution is in the frequency domain or the time domain.

Listing A-8. Procedure CONVOL

```
//CONVOLH  PROC TIM=OLD,FRQ=OLD
//* TOM HARRIS,303-599-1745, 1 JULY 1980    , INDEFINITE
//* COMPUTES CONVOLUTION
//*
//*     THIS PROCEDURE EXECUTES THE CONVOLUTION MAINLINE PROGRAM.
//*     IT COMPUTES EITHER A TIME DOMAIN CONVOLUTION OF THE IMPULSE RESPONSE
//*     AND EFIELD DRIVE, OR A FREQUENCY DOMAIN PRODUCT  OF THE FREQUENCY
//*     DOMAIN RESPONSE AND FREQUENCY DOMAIN EFIELD DRIVE.
//*
//LKED EXEC    PGM=IEWL,REGION=250K,PARM='NOMAP,LIST,NOXREF,LET'
//SYSPRINT DD DUMMY
//SYSLIB    DD DSN='HK3014.TEMP04',DISP=SHR
//          DD DSN=SYS1.FORTLIB,DISP=SHR
//SYSUT1    DD UNIT=SYSDA,SPACE=(1024,(200,20))
//SYSLMOD   DD DSN=&&GOSET(MAIN),UNIT=SYSDA,DISP=(,PASS),
//             SPACE=(TRK,(10,10,2))
//SYSLIN    DD DSN=HK3014.LKEDIN4(CONVOL),DISP=SHR
//CONV    EXEC PGM=*.LKED.SYSLMOD,COND=(8,LT,LKED)
//FT02F001  DD   DSN=&&ID,DISP=(OLD,PASS)
//FT03F001  DD   DSN=&&FIMP,DISP=(OLD,PASS)
//FT04F001  DD   DSN=&&IMPLS,DISP=(OLD,PASS)
//FT05F001  DD   DSN=&&FIELD,DISP=(OLD,PASS)
//FT06F001  DD   DSN=&&PRINT,DISP=(MOD,PASS)
//FT08F001  DD   DSN=&&FFIELD,DISP=(OLD,PASS)
//FT09F001  DD   DSN=&&FPROD,DISP=(&FRQ,PASS)
//FT10F001  DD   DSN=&&RESP,DISP=(&TIM,PASS)
//DD1   DD   DSN=&&GOSET,DISP=(OLD,DELETE)
```

## A-9. PROCEDURE OUT

Procedure OUT (listing A-9) loads and executes program OUT. The default value of OFFPLOT = 'HKZ001.OFFPLOT' allows the user to write output to the bed plotter on magnetic tape for subsequent off-line plotting. The substitutable parameter OFFPLOT must be set equal to SYS1.DUMMYLIB for on-line plotting. The default value of HLDPLT = YES allows the output to the plotter to be placed in hold so that the operator can mount a magnetic tape for the off-line plot option. Otherwise, the user must specify HLDPLT = NO on the EXEC statement. Substitutable parameters SYST and HLDPRT are used when a job is submitted through TSO and it is desired to recover the output at the TSO terminal such as a plot on the teletypewriter. In that case, the user must set SYST = Z and HLDPRT = YES. The output can then be recovered at the TSO terminal by issuing the OUTPUT (JOBID) command.

Listing A-9. Procedure OUT

```
//OUTH      PROC OFFPLOT='HK3014.OFFPLOT',SYST=A,HLDPLT=YES,HLDPRT=NO,
//               DIS=PASS,PUN=B
//* TOM HARRIS,303-599-1745, 1 JULY 1980    , INDEFINITE
//* OUTPUT ROUTINE
//*
//*     THIS PROCEDURE PLOTS THE OUTPUT RESULTS FROM TEMPO AS CONTROLLED
//*     BY  THE IOFLAGS IN THE IO DATA DECK
//*
//LKED EXEC     PGM=IEWL,REGION=250K,PARM='NOMAP,LIST,NOXREF,LET'
//SYSPRINT DD DUMMY
//SYSLIB    DD DSN=&OFFPLOT,DISP=SHR
//             DD DSN='HK3010.ANAPAC',DISP=SHR
//            DD DSN=SYS1.FORTLIB,DISP=SHR
//            DD DSN=SYS1.PAGLOAD,DISP=SHR
//    DD DSN='HK3014.TEMPO4',DISP=SHR
//SYSUT1    DD UNIT=SYSDA,SPACE=(1024,(200,20))
//SYSLMOD   DD DSN=&&GOSET(MAIN),UNIT=SYSDA,DISP=(,PASS),
//               SPACE=(TRK,(10,10,2))
//SYSLIN    DD DSN=HK3014.LKEDIN4(OUT),DISP=SHR
//OUT       EXEC PGM=*.LKED.SYSLMOD,COND=(8,LT,LKED)
//FT01F001   DD   UNIT=VIO,DISP=(,PASS),SPACE=(CYL,(1,1))
//FT02F001   DD   DSN=&&IO,DISP=(OLD,DELETE)
//FT03F001   DD   DSN=&&FIMP,DISP=(OLD,DELETE)
//FT04F001   DD   DSN=&&IMPLS,DISP=(OLD,DELETE)
//FT05F001   DD   DSN=&&FIELD,DISP=(OLD,DELETE)
//FT06F001   DD   DSN=&&PRINT,DISP=(MOD,PASS)
//FT08F001   DD   DSN=&&FFIELD,DISP=(OLD,DELETE)
//FT09F001   DD   DSN=&&FPROD,DISP=(OLD,&DIS)
//FT10F001   DD   DSN=&&RESP,DISP=(OLD,&DIS)
//FT11F001   DD   DSN=&&ZA,DISP=(OLD,&DIS)
//FT12F001   DD   UNIT=VIO,DISP=(,PASS),SPACE=(CYL,(1,1))
//FT20F001   DD   DSN=&&NLIN,DISP=(OLD,DELETE)
//        EXEC   PGM=IEBGENER,COND=EVEN
//SYSIN DD DUMMY
//SYSPRINT DD DUMMY
//SYSUT1 DD DSN=&&PRINT,DISP=(OLD,DELETE)
//SYSUT2 DD SYSOUT=&SYST,HOLD=&HLDPRT
//DD1   DD   DSN=&&GOSET,DISP=(OLD,DELETE)
//        EXEC   PGM=IEBGENER,COND=EVEN
//SYSIN DD DUMMY
//SYSPRINT DD DUMMY
//SYSUT1 DD DSN=&&PUNDATA,DISP=(OLD,DELETE)
//SYSUT2 DD SYSOUT=&PUN,HOLD=&HLDPLT
```

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